GEOGRAPHICAL BOTANY.

In presenting to the readers of this report the very able and complete essay upon the derivation of Indiana's flora, prepared by Professors J. M. Coulter and Harvey Thompson, of Wabash College, it has been thought advisable to prefix, by way of introduction, an outline sketch of Geographical Botany, with a view to making Professor Coulter's special conclusions the more striking and effective under the light of certain generalizations of other botanists.

Gray and Bentham have, with the help of many other faithful workers in the study of plant distribution, rendered it possible for us to divide, with tolerable clearness, the vegetable life on the earth's surface into three floras; these floras have been named the Northern, the Southern, and the Tropical.

The Northern Flora, in a general way, may be said to inhabit Central and Northern Asia, Europe and most of North America.

The Southern Flora has for its habitat all of South America, save the tropical belt, South Africa, New Zealand and Australia.

The Tropical Flora, as its name indicates, exists chiefly within the tropical zone.

But it must be understood that the floras thus designated as Northern, Southern and Tropical are not at present actually confined to the limits of their respective habitats, and it is the fact that the floras show disturbances, transmigrations, transplantings and interminglings almost inexplicable, that has made Geographical Botany a most interesting and extremely difficult study. It is this fact, too, that has, in recent years, given a strong impulse to the study of paleozoic floras, for the farther back we can trace and analyze the life, habits and environments of plants, together with the changes in the superficial and internal features of the earth, and with the attendant phenomena of climate, etc., the more readily shall we comprehend the problems of plant movements. The first thing for the student to accomplish, if possible, in connection with this study, is to drive from his mind the standard of years or centuries in the measurement of time. Plants have existed on the earth for perhaps hundreds of thousand of years. There is no way of measuring even the most recent grand geological period. Therefore, when it is said that at some point in

the past a Tropical Flora inhabited Indiana, and that afterward an Arctic Flora prevailed, it is not meant that the change came about in a few years or in a few thousand years. Infinite slowness of progress and recession is the law by which nature has been controlled in all her great operations. Thus, in explanation to some extent of the fact that, as the glacial age came on, the tropical and sub-tropical plants migrated southward from Indiana, I may say that they could have traveled fast enough to keep within the proper temperature by the mere process of leaning towards the sun, and by dropping their seeds a few inches farther southward each year. It is a fact that plants do lean and grow towards light and heat, and it would seem that this has been one of the great factors in plant movement toward the south and west. Without entering into the details here, it may safely be said that plant migrations are slower northward than southward (north of the equator and the reverse south of that line) on account of this leaning of plants toward the sun. In other words, as a general rule the plants of a Tropical Flora, by the almost infinitely gradual process of leaning toward the sun and dropping their seed, will, if far north of their habitat, travel toward the area whose temperature is best suited to their wants. On the other hand, the natural movement of an arctic plant toward the north would depend more upon the accidents of wind, water, bird-migration, the reach of seed-bearing branches on the north side of the plants, etc.

It appears to be a law of plant life that the structure of an individual makes a movement toward accommodating itself to any change of climatic environment, and there can be little doubt that many living plants are but modified forms from an ancestry whose habitat was controlled by a very different climate from that now best suited to their growth and development. Thus it would appear that as late as toward the close of the Tertiary age, the north polar regions were inhabited by a flora suited to a much warmer climate than now prevails there, and that as the climate grew gradually colder and colder, both modification and southward migration began. The result would be a blending of these modified forms with the flora of the north temperate region.

South of the equator migration and modification would be toward the north, that is toward the equator.

It is true, however, that plants will travel with more or less rapidity in every direction if not obstructed by some physical hinderance, and a mere change in the character of the soil may be such a hinderance, or it may be sufficient to enforce a great modification of the plants in the course of a long period of time.

All over the earth there are evidences, more or less marked, of plant migrations, some of which point to very great changes in the land surface, in climatic conditions and in the nature of soil, brought about by forces whose origin is at best a matter of scientific inference.

At present in extreme polar areas arborescent plants do not exist, and, indeed, the flora is almost wholly limited to little perennial plants of rapid growth, capable of maturing their seeds in the mere flash of summer that comes to them on those bleak deserts of ice and snow. As we pass farther south vegetation becomes stronger; stout shrubs and stunted-looking trees begin to appear, the size and beauty as well as the number of plants increasing until the maximum is reached in the temperate and tropical zones.

As sea-currents and sea-winds greatly influence climate, we shall find a striking modification of floras on sea coasts, when compared with the floras of the high interior lands of continents. So upon islands it has been observed that in some instances a peculiar flora has been preserved on account of isolation, the sea-barrier preventing migration or immigration. Along the Atlantic coast of North America, some trace of a sub-tropical, that is, a modified Tropical Flora, reaches up to Virginia, and the arborescent flora of the Pacific coast is wonderfully modified and developed. So the combined effect of soil and meteorological influences is shown in the floras of great valleys extending into continents from the seas. Not less marked is the character of the floras of high mountain ranges. The peculiar nature of some island floras has been mentioned. Madagascar is an interesting instance for study, where a number of plant species are found that belong to Asia, and are unknown in Africa, and where already a large number of genera peculiar to Madagascar has been discovered, although the island is but a short distance from the main land of Africa. Malayan and Australian types of plants are also found in Madagascar.

If it would be going too far to say that plants now found only within a restricted area were created there in the beginning, it certainly would be still more against probability to assert that there is no connection in fact between kindred or identical species found in widely separated and isolated spots. In this connection it may be stated that the sex of a plant or a flower depends largely upon the amount of nutrition it receives. This fact controls, in a great degree, the position of the seeds on plants. Thus the conifers bear their cones on those branches which reach the light, and, indeed, it will be found that the heaviest fruitage, in the case of most trees, will be found on the side best exposed to the sun. That this fact points to one of the most efficient agencies in plant migration there can be no doubt whatever. The branches on the side toward the sun will usually receive the most nutrition, and hence bear the fruit and seed-producing flowers in larger number than will those on the side opposite the sun, hence the falling of most seed will be on the southern or south-western side, and that will be the principal direction of migration, all other things being equal.

We know by observation that plants are disposed to take care of themselves. If the seed of a light-loving species germinate in a dark apart-

ment, its plant will unerringly grow toward the aperture through which a ray of sunlight and sun-heat may come. Here is a definite and decided evidence of the impulse in plants to travel toward their proper climate. Knowing this fact, we may at once account for the tendency of a large number of plants of our hemisphere to most readily migrate in a southerly or westerly direction, as those are the directions from which the sun pours its greatest effective volume of light and heat. This, too, is in perfect accord with the great general fact of Paleontological Botany. Prior to the coming on of the glacial period, a Tropical Flora existed far northward. It is not known what caused this, but it appears probable that great seas and tropical sea-currents long since destroyed, were, as like seas and currents are now, important agents influencing climate. As the seas withdrew southward and soil was formed, plants followed the beck of the sun and migrated from a habitat which gradually grew too cold for them until there came a time, when, here in Indiana, the climate was too frigid for even an Arctic Flora.

In places where the old soil of the Quaternary in Indiana underlies the Drift, remains of plants have been found. These represent mostly hardy cedars and the smaller arborescent growths of a cold climate, which would show that before the glaciers passed over our State the temperature had become intensely arctic, and that those icy visitors were not mere mountain-glaciers, like those now moving down the Alp-slopes.

In the course of great physical and climatic changes, wrought by slowly-acting forces with the ultimate effect of cataclysms, certain land areas were protected by the accidents of configuration and situation, and these became isolated gardens, so to speak, for the preservation and subsequent distribution of floras.

These areas of preservation and lines of migration are dimly sketched throughout the paleozoic records of plant life, and may be traced down to the present time with at least a degree of certainty.

The great labor and extraordinary abilities of Lesquereux have thrown a strong light upon paleozoic botany in America, and his discoveries go far toward explaining, in a general way, some of the great plant migrations of this continent. He has more than suggested that our present arborescent flora may be traced back through successive geologic formations into the Tertiary rocks, which would indicate an origin here, but the fossil remains of plants are so meager, comparatively speaking, that such a conclusion must be largely conjectural. Our knowledge of geographical conditions during the paleozoic ages rests upon such slight evidence that it is impossible for us to say what land connections between continents may have existed formerly, or what great highways of travel once used by plants have been destroyed. If it is a labor almost superhuman to construct an outline of geographical botany with relation to existing plants, how much harder to apply the strict rules to the scattered and fragment-

ary remains of paleozoic floras? Still, a wonderful progress has been made. Thus it has been shown that there is a close relationship between the American flora and that of the Miocene of Europe, a fact which may point with much force to a former connection of the continents. So it has been suggested, on the strength of many botanical facts, that formerly there existed a land-way of migration between the tropical parts of Africa and America.

When the floras of tropical countries shall have been better studied, it may appear that during the Tertiary ages the tropical zone was, over much of its area, too arid and burning to admit of a numerous flora, and that it was not until during the glacial period that many of the tropical plants reached their present habitat. It will be seen, therefore, that a thorough knowledge of geographical botany must largely depend upon gathering and grouping the facts of vegetable paleontology in connection with a complete study of existing floras. Nor must we depend solely upon a knowledge of botany. There is such a correlation between plant life and animal life, that the study of one must involve a study of the other. Animals, from the largest mammal down to the smallest insect, are many of them dependent wholly or in part upon plants for their food, their homes and their general comfort. Certain animals, on this account, are found associated with certain plants, a fact of large importance in the study of geographical botany, both ancient and recent. Where traces of the animal are found its food may be inferred, and the converse. For instance, if we find the remains of arboreal animals in a certain deposit, the inference is strong that trees existed there. The remains of bees and humming-birds would suggest flowering plants of a kind suited to the habits of particular species. Darwin, in his great work on the Origin of Species, has indicated in a masterly way the true lines of study. The environment speaks of its own influence and we shall nowhere find any great area entirely without a direct contribution to the needs of life. Moreover it is life that is flexible to the force of condition—life that ever becomes the infinitely variable quantity in Nature, affected at every point by the influences of climate, soil, food, configuration of the earth's surface, and those accidents due to time and place. Plant-life, owing to the peculiarity of the plant's methods of locomotion, is exposed to every possible assault, and it is to its elasticity and flexibility, to ready and prompt rearrangement of its lines, that it survives with such stubborn vigor after all the extremes of accident and revolution to which it has been subjected since the earliest geological records.

During the course of extensive observation in the United States, over a rather wide strip of country reaching from the peninsula of Florida to that of Upper Michigan, I have noted some very interesting facts in connection with plant-migration and the survival of plants in certain spots after the conditions best suited to their existence have long been dispersed.

High up in the mountains of North Georgia, at the edge of a boggy "pocket," I found the small, scented yellow lady's-slipper (*Cypripedium parviflorum*) growing to perfection. I have observed it nowhere else south of the Ohio River. So *Arethusa bulbosa* was found on a bog not far from Tallahassee, Florida. On the other hand, *Smilax Walteri* was noted in the summer of 1877 on the edge of a swamp on the sandy point of the Leelanau Peninsula of Michigan. It is worthy of remark that low down on the Florida Peninsula, so far as my observations have gone, very few northern plants, save those aquatic or semi-aquatic, are to be seen, while among the hills, from Macon to Tallahassee, many species appear that are common as far north as the forty-second parallel of latitude.

It is this overflowing of floras—this washing back and forth of the vegetable tides—that has made the study of Geographical Botany so intricate and difficult.

So far as paleontological botany has been studied, the conditions of plant-life appear to have been much simpler in the remote past than they are now, but we are left with very slender materials upon which to found our opinions in this regard. True, the Carboniferous strata are rich in vegetable remains; but the judicial mind is struck with the paucity of genuine evidence tending to support any theory exclusively. The plant fossils lie mostly above and below the coal deposits and are in turn pressed above and below by masses of marine animal remains. As compared with the area to be studied the exposures are extremely meager and the fossils found are in a large degree fragmentary, greatly modified by pressure, their structure obscured by chemical and other influences, and a greater part of their most delicate and characteristic markings destroyed. Still, the indefatigable specialists have collected a mass of facts telling a story sufficiently connected to sketch some very valuable outlines. If we accept the theory that coal has been formed in bogs, as peat is now forming, or, if we agree that coal is the result of the gradual submerging of great shore marshes, the fact still remains that the species of plants from which the deposit has been formed are not more than two or three hundred in number in any place. This might at first view appear to suggest a scant flora, but we must remember that the main bulk of the coal-bed itself is a mass of vegetable matter, so to speak, whose forms, perhaps very numerous, have been entirely destroyed.

Land plants have been pretty clearly identified as far back as the middle Silurian.

Vascular cryptogams begin in the Devonian and pass up through the Carboniferous strata into the Permian. These appear to have been chiefly ferns and plants of the horse-tail family (*Lycopodiaceæ* and *Equisetaceæ*), but there were also certain phenogamous gymnosperms belonging apparently to a group of plants which, as Lesquereux suggests, held an intermediate place between the *Cycadeæ* and the *Coniferæ*, with a close kinship to the latter.

It is impossible to give details here, but taking the fact that the genus *Cordaites*, for instance, persists in passing from the Devonian on up through the Carboniferous rocks, it is safe to say that the species migrated during those ages and occupied every available exposure of soil-area. The land-surface rose and sank, was above water for long periods of time and below water for periods equally great, but with each appearance of soil-bearing surface above the sea, the plants claimed their home and set forth to occupy it. This truth is beautifully evidenced by the strata of the Coal-Measure rocks. There we see the same thing recurring again and again. Sedimentary marine deposits alternating with accumulations of vegetable remains, showing that time and again the sea covered the land and destroyed all plants and covered them deep under mud and shells and sand, and that just as often when the sea retired the plants came again to the old haunts and stubbornly maintained their right to grow and thrive there. Thus each sandstone that bears plant impressions and each stratum of carboniferous shale wherein the Coal-Measure plants abound, may be taken to signify the migration of plant-species in Paleozoic times. Again, in the Mesozoic the appearance of certain plants, the *Yuccites*, for instance, points to the same conclusions. So, in the Cretaceous and on up through the Eocene into the present age, the monocotyledenous plants have covered and recovered the same area again and again.

In the Cretaceous rocks known as the Dakota group appear the *Dicotyledons*, with forms familiar to our time, as has been shown by Lesquereux. There flourished the oak, the poplar, the beech, the birch, etc.; even the apple and plum were there.

But even successive growths of plants differing widely in their genus or species will be found suggestive of migrations and re-migrations. The processes of time and the action of accidental or cyclical forces have, no doubt, changed many species to such an extent as to cause every distinct trace of their origin to disappear, and on this account what we now regard as a new genus may be the modification of an old species. At all events, the proofs are sufficient to warrant the conclusion that from the most ancient geologic periods of plant-life down to the great glaciers which destroyed everything as far as they went, the migration of plants is recorded in the rocks. During the coldest period of the glacial age it is probable that even at the Tropics the temperature was much lower than that of our latitude now, excepting in such favored areas as were exposed to the genial influences of warm sea-currents. It is difficult, with our present knowledge of Geographical Botany, to discover those areas of preservation from which, as centers, the plants marched forth, after the final recession of the glaciers, to recapture their homes; but when the botany of every country on the globe shall have been studied and reported upon as carefully as Professors Coulter and Thompson have done with Indiana, we shall be able to approximate the truth in this regard. Professor Coulter's conclusions are amply sustained by the proof as indicated

in his catalogues, and the fact that geology supports botany is but another evidence of that perfect accord which exists between cognate branches of natural science or, in other words, that accord which is the law of nature.

In looking over the results of the most careful botanical work done within the last twenty years, and especially the work done in phyto-paleontology, one is struck by the fact that at least four strong lines of land plant-life have come up to our time from the Silurian, to wit: The *Ferns*, the *Equisitineæ*, the *Lycopodineæ* and the *Coniferæ*, while but two have come from the Devonian, the *Cycadaceæ* and the *Monocotyledons*, and but one from the Mesozoic, the *Dicotyledons*. These lines of plant-life may be said to represent the chief types of land vegetation. The value attached to a consideration of them here is in the evidence they give tending to prove that plants have preserved themselves through countless ages of changing conditions largely by means of migration to and fro and by structural modification to suit varying exigencies of climate and environment.

In those areas which have been subjected to the great glacial forces—and Indiana is a part of such an area—the study of plant movements is rendered vexatiously difficult by the want of permanency in the configuration of the land-surface. So-called "glacial deposits" are, from their very nature, subject to rapid erosions and re-arrangements by the forces of water and air.

In Indiana the glacial deposit lies upon the Carboniferous. The Mesozoic and Cenozoic formations are wanting. Through this glacial deposit or "Drift," as it is called, our rivers and brooks and spring-streams have cut deep valleys, channels and ruts, while the action of rains and winds has been affecting the surface from the date of its deposit to the present time. It will be seen at once that these conditions render the area in some regards more difficult to study than that of a mountain range. In the extreme southern part of the State, where the Drift disappears, the surface is an irregular succession of "Knobs," and is cut in every direction by a net-work of deep, dark ravines, whose final outlet is into the Ohio River, on one hand, and into the Wabash on the other hand. It is in the south-western corner of this driftless area that is found marked evidence of a small center of preservation wherein are found species belonging to a sub-tropical flora. South-eastern Missouri presents a like area, and it will be seen that Professor Coulter, following the suggestion of Professor Collett and Dr. Phinney, has shown an area in Indiana where a northern or north-eastern flora appears to have come into Indiana from the east and north, and to have been preserved on certain high lands.

It is greatly to be regretted that the systematic study of the botany of Indiana has been begun too late for the best results to flow therefrom. The effect of a remarkably clean and careful agriculture has been to annihilate many of our most interesting species of plants, and this before a

perfect geographical study has been completed; but Professor Coulter's catalogues, and his paper therewith presented embody the facts as collected to date, and will be found of great value.

The student will do well to elaborate by field work the suggestions these facts contain, for it is by verifying written accounts by the living records of Nature that we may hope to eliminate errors and arrive at the nearest point to truth.

The key to scientific progress is to be found in comparative observations made from every possible point of view, and it must be kept in mind all the time that contemporaneous botany is not to be understood in all its parts without a good knowledge of paleontology. Indeed, the fairest field now reserved for the botanist is that comprehending the relationship between the ancient and present floras, and the biologic meanings to be deduced therefrom are of the highest importance to the understanding of plant-life in its broadest scope.

So far as observation has gone at present, the chief periods of plant diffusion and development in the past would appear to have been in the Permo-Carboniferous and in the Upper Cenozoic; but if we could be sure that our coal-beds are the result of a general mixed vegetation, and not mainly of a peat-bog growth, we should be forced to conclude that at no period has plant-life flourished with such amazing luxuriance as during the formation of the Coal-Measure rocks. The upper Trias and lower Cretaceous are so weak in plant remains as to suggest that during those periods the areas of plant-life must have been very restricted and that it required a long geologic period for vegetation to spread over the vast surfaces it had occupied at the close of the Eocene, and the slight evidences of any great development anywhere during the Quaternary, gives us a criterion by which to measure the amazing advances of streams of plant-life since the glacial period.

At the time when the southern margin of the great glacier was along the Ohio River, there was probably a vast snow-field, like those of Greenland, stretching down to the Gulf of Mexico, and the only plants then growing on this continent were embraced in a fringe of Arctic vegetation on its southernmost boundary. As the glaciers retreated northward, there was a gradual march of plants in their wake. Probably the first path of migration northward was led, under the genial guidance of the Gulf Stream, along the Gulf and Atlantic coasts; for while yet the ice-currents were active on the northern slope of the Ohio valley, the great sea-current had warmed the shore of the Atlantic and had coaxed colonies of venturesome plants to creep far up the coast toward Canada. In those days all the migratory birds no doubt followed the shore-line, as many of them still do, and they greatly assisted in advancing vegetation by bearing seeds with them on their northern journeys. The Gulf Stream, too, was doubtless a great seed-bearer.

The fact that aquatic birds would be the first and most venturesome emigrants naturally suggests that aquatic and semi-aquatic plants might lead the van in this great movement of vegetation up the Atlantic border. The Gulf Stream, too, would be most likely to be the bearer of bulbs, roots and seeds of water plants, and of plants growing upon water margins.

The next great line of bird migration, and consequently of plant movement, would be up the Mississippi Valley. In this case the conditions would be similar to those on the Atlantic Coast, the aquatic birds, following the course of the river, would bear seeds of aquatic and marsh plants and drop them along the way. It would be only in the most favored spots that these seeds would germinate and gain a hold.

Now, what facts do we observe bearing out the foregoing conclusions? Did aquatic, semi-aquatic and riparian plants lead migration?

Nelumbium luteum is found as far north as New York on the Atlantic Coast, and common far up the Mississippi Valley.

Nymphæa odorata shows itself all along the Atlantic Coast, and has followed the lines of water-fowl migration.

Nuphar advena is everywhere in the paths of the water birds.

Hydrocotyle umbellata runs up the coast to Massachusetts.

The *Limnobium spongia* has taken up its abode far up in our northern lakes. So with the *pickerel-weed* and *water-oats*.

Quercus aquatica reaches northward into Maryland, and far up the Mississippi Valley, though its proper home is in the sub-tropic belt.

Taxodium distichum has followed both the Mississippi Valley and the Atlantic Coast to a rather high latitude, and has run up the Ohio Valley as far as to Indiana.

Some of the subtropical rushes are found as far north as New England, while bear-grass comes up into the Ohio Valley, and the *Sedge family*, with its multitudinous rush-like and grass-like plants, has followed the water birds all along all their lines of migration.

The foregoing list might be extended to fill many pages, but space is wanting, and this paper does not call for it. The plants I have chosen to mention are all of a character unsuited to rapid migration by the operation of their own powers. The strong inference, aside from any further proof, would be that we should find the great body of vegetation following the same lines of migration, and that a large number of Indiana's plants could be traced, in a general way, from three great centers, viz: The Atlantic Coast, the Ohio River margin and the Mississippi Valley.

The preservation of plants in certain areas of this State must be referred chiefly to local accidents of land-surface configuration, as Professor Coulter has shown, and these foreign residents must be viewed as mere loiterers whose favored situations has exempted them from climatic effects.

It is not out of place to close this hasty sketch with the statement of a fact illustrative of how easily and rapidly a plant may invade any given territory. During the Ohio River flood of 1882 seeds of the *Sweet-clover* (*Melilotus alba*) were brought by the stream to Dearborn County, and since then the plant has appeared in places over an area of about two hundred square miles. According to observations by Professor S. S. Gorby the agility, so to speak, and the persistency of this stranger have proved to be wonderful. It has climbed barren hill-sides and crossed over rocky barriers with the greatest of ease, appearing to halt at no obstacle. It is not an American plant, but it soon will be a duly naturalized citizen.